NFPA 329

UNDERGROUND LEAKAGE OF FLAMMATORY AND COMBUSTIBLE LIQUIDS

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(c) Check vegetation in the area for any indication of damage by spillage, dumping or contaminated ground-water.

(d) Using a combustible gas indicator, check sewers and other underground cavities such as telephone and utility conduit manholes for presence of vapors and make visual inspection for signs of foreign liquids on water surfaces.

(e) Check nearby excavations and steep cuts or natural slopes below the potential source for signs of liquid coming through the soil.

3-2.2.4.2 When leaks in equipment are discovered, ask the user and owner to stop use of the equipment until the leak is repaired. Pump out liquid in storage if it is still escaping through the leak.

3-2.2.4.3 If large spills have been reported or there are indications that there has been repeated dumping or spilling of flammable or combustible liquids into sewers or on the ground, ask those involved to modify their operations to prevent recurrence.

3-2.2.4.4 Be reasonable and fair; recognize that small spills may inadvertently occur and that a very small amount of petroleum liquid (just one cup of gasoline, for example) on a wet pavement will spread over a large area, appearing to be a more severe spill than it actually is. Spills on the surface that spread out will dissipate rapidly and are not likely sources of underground contamination. The significant spills are large spills that can flow to points of access to underground structures or areas of porous soil, or repeated smaller spills that immediately flow into structures or soak into soils and reach the water table.

3-2.2.4.5 If an obvious source, or one or more likely sources, has been found and further escape of liquids eliminated, further search may be temporarily suspended to determine whether, in fact, the located source(s) is the cause of the problem. While removal and protective measures are taken, monitor and record the flow of liquid, the amount of liquid, and the vapor concentration at those locations where the problem exists. If there is a distinct and continuous decrease it may be assumed that the source(s) has been found and further contamination eliminated. The decrease may not show up immediately; it may, in fact, require days or weeks to remove liquid that has accumulated underground or for it to dissipate. Refer to Chapter 5, "Tracing Liquids Underground," to determine how much time may be required before a decrease at the monitoring point may be expected.

3-2.2.4.6 If, after a reasonable length of time as determined with the reference above, the supply of liquid to the threatened area does not stop or show definite decrease, further investigation should be conducted simultaneously along two paths. These two paths also should be followed if no source is found.

3-2.2.4.7 One path is to test flammable or combustible liquid storage and handling equipment in the vicinity of the contaminated area; the other is to trace the liquid underground from its point of discovery. Tracing is conducted to determine the extent of the contamination, the direction of flow, and any potential more remote source(s). Tests on underground equipment are performed to determine definitely whether or not they are a source. (*See Chapter 4, "Testing for Underground Leaks," and Chapter 5, "Tracing Liquids Underground."*)

Chapter 4 Testing for Underground Leaks

4-1 General.

4-1.1 Tests to determine the tightness of underground liquid-handling equipment will have to be conducted when:

(a) The search procedures of Chapter 3 or the tracing procedures of Chapter 5 indicate a probable or likely leakage source, but the actual cause is not determined from surface observation;

(b) There is a suspicion of a leak because of reported stock losses;

(c) There is a report of the accumulation of water in a tank.

4-1.2 Review all data previously gathered to determine the most efficient method or methods of testing. There are several quick and simple tests described in this chapter that may reveal a leak under certain circumstances. If one of these preliminary tests does not reveal the source of a suspected leak, it cannot be concluded that the liquid-handling system is tight, but the possibility of quickly solving the problem will often warrant the limited effort involved before a Precision Test is undertaken. (*See 4-3.11.*)

4-1.3 One or more of these preliminary tests would be particularly desirable if Precision Test equipment is not immediately available. If such equipment is available, time and labor costs may be reduced by immediately making a Precision Test.

4-1.4 Regardless of the testing procedure involved, keep in mind that liquid-handling equipment should be tested in a condition as close as possible to operating conditions. Excessive pressures or tests by nonrepresentative liquids may indicate leaks where none exists or conceal leaks where one, in fact, exists.

4-2 Action Preliminary to Testing.

4-2.1 Before actual equipment testing is undertaken, review the results of the primary search in Chapter 3. This review may reveal information that will eliminate the need for further testing or this information will be useful in making further tests.

4-2.2 Ensure that spills or deliberate disposal are not the leakage source, keeping in mind the possible transit of liquids by trenches and underground water. (*See Chapter 5.*)

4-2.3 Recheck stock records for indications of loss; but do *not* jump to conclusions. Meters may be off calibration, causing only a paper loss, not a physical loss.

4-2.4 Temperature change may falsely indicate a loss. The volume of petroleum products is highly sensitive to temperature change. A drop of one degree Fahrenheit will shrink 1000 gal (3785 L) of gasoline by "0.7" gal (2.2 L). This may at first seem small but consider a typical example. In the spring, the ground will still be relatively cool from the preceding cold weather, while liquids stored and transported aboveground may be relatively warm.

4-2.5 A typical underground gasoline storage tank may handle 20,000 gal (75 700 L) in one month. If, on the average, this liquid cooled 5°F (2.8°C) after delivery, stock records will show a loss of 5 × 0.7 × 20 = 70 gal (265 L). Ten degrees cooling would appear as a 140-gal (530-L) loss for 20,000 gal (75 700 L) handled, and a 280-gal (1060-L) loss for 40,000 gal (151 400 L) handled. Obviously, a temperature increase would have the opposite effect and could actually conceal a physical loss.

4-2.6 Finally, theft may be the cause of reported stock loss.

4-2.7 Consequently, further checking must be performed before a facility is implicated on book stock losses alone. Check meters for calibration. Check relative temperature of delivered and stored product during the period in question. Check for the possibility of theft.

4-3 Checking Inventory Records.

4-3.1 A careful check of inventory records will be very helpful in determining the course of further investigation. (*See Appendix B for a description of inventory control procedures.*)

4-3.1.1 If the reason for the check is a report of loss of inventory but no liquid or vapor has been reported in unexpected locations:

(a) Loss due to meters out of correct calibration, loss by contraction due to lower temperatures, or theft would indicate that a hazard need not be expected. Further testing is not necessary;

(b) If not solved as in (a), evidence of an inventory loss requires further testing to determine the cause. It also indicates that a potential hazard may develop from the escaped liquids and a check of the surrounding area should be made for signs of contamination. (*See 3-2.2.4 through 3-2.2.4.7.*)

4-3.1.2 If the reason for the check is discovery of escaped liquids or vapors found underground:

(a) Evidence of inventory loss strongly implies the source has been found but subsequent checks to determine how the loss has occurred must be made before definite conclusions can be drawn;

(b) Loss partially or totally explained by off-calibration meters, temperature shrinkage, or theft cannot be considered as conclusive evidence that the site in question is not a source. Records are often incorrect or inadequate: unless another source is found and considered to be a satisfactory solution to the problem, other tests must be performed to draw definite conclusions.

4-3.1.3 In tank monitoring systems that incorporate automatic gauging equipment may be used to accomplish inventory control and to indicate possible leakage.

4-3.2 Pressure Testing with Air or Other Gases. Pressure testing, with air or other gases, of tanks or piping containing flammable or combustible liquids is not recommended, should not be required by regulations or ordinances, and should be discouraged in practice. Such tests are not likely to detect a leak that is below the liquid level in the tank, and there is severe danger of causing a tank rupture, or expulsion of contained liquid through normal openings.

NOTE. There are systems that use unique gases that are not dependent on pressure for detection of leaks.

4-3.3 Testing Underground Facilities.

4-3.3.1 Using the information gained from the primary search procedure (*see Section 3-2*), use the following tests in a logical process of elimination. For example, if water is reported as entering a tank, or if the tanks are old and corrosion is known to exist in the area, make the preliminary checks on the tanks first. On the other hand, if pumping troubles are reported, the piping is suspected and preliminary tests should be performed on underground piping first.

4-3.3.2 The tests described on the following pages are listed in approximate order of ease of performance, the easiest being first. The sequence should be varied to fit the circumstances, as noted in the preceding paragraph.

4-3.4 Checking Underground Pipe.

4-3.4.1 Check for:

(a) Recent digging, driveway repair, or other work in the area which may have damaged underground lines.

(b) Any recent repairs that may have been made indicating a previous leak or perhaps creating a leak due to faulty work.

(c) Any evidence of shifting ground, such as frost heave, which may have damaged lines.

(d) Soft spots in asphalt paving indicating solvent action of liquids or vapor.

4-3.4.2 If information on the location of liquid underground has been compiled by methods described in Chapter 5, "Tracing Liquids Underground," review this information for possible patterns that may indicate a specific pipe is likely to be the source. It may be advisable to drive or drill additional holes to define more definitely where the liquids are and how they are flowing. (Review in particular the information in connection with Figure 10 in Chapter 5.)

4-3.4.3 The test to be used on piping will depend on the method used to move or pump the stored liquid.

4-3.5 Hydrostatic Test of Piping. Isolate the piping and conduct a hydrostatic pressure test at 150 percent of the maximum anticipated pressure of the system, but not less than 5 lb per sq in. (34.48 kPa) gauge at the highest point of the system. The test should be maintained for at least 10 minutes. If the pressure drops, it indicates the possibility of a leak in the piping and it is recommended that a volumetric test be performed. It should be noted that a loss of liquid pressure can be attributed to the following: a line leak; a decrease in liquid temperature in the line; piping distortion due to the liquid pressure; or entrapped vapor in the piping. Accumulated liquid loss during a volumetric test of more than 0.05 gallons (0.19 liters) per hour during timed restoration may indicate a leak in the piping.

4-3.6 Suction Line Testing.

4-3.6.1 If the pump used in moving the liquid is above ground, the supply pipe operates under vacuum or suction and certain pumping characteristics indicate either a leaking check valve or a leaking pipe. If there is a leak, air will enter the pipe as liquid drains back into the tank through the check valve or through a pipe leak into the ground. The presence of air will be indicated by the action of the pump in the first few seconds of operation after an idle period. If the pump is equipped with a meter and cost/quantity display device such as is found in a gasoline service station, pumping of air is indicated by the display wheels skipping or jumping. Other indications of air in the suction line are:

(a) The pump is running but not pumping liquid.

(b) The pump seems to overspeed when first turned on and then slow down as it begins to pump liquid.

(c) A rattling sound in the pump and erratic liquid flow indicates air and liquid are mixed.

4-3.6.2 If any of the preceding conditions indicate a leak in the suction line, the check valve should be inspected first. Some check valves are located close to the pump inlet, others are mounted in the underground pipe just above the tank, and some may be on the end of the suction stub inside the tank. Some of those valves located in the pipe above the tank can be inspected and repaired from the surface of the ground through a special extractor mechanism installed with the valve. If not, or if the valve is inside the tank, it may be necessary to dig down to the tank to check the valve or disconnect and seal off the pipe for a hydrostatic pressure test.

4-3.6.3 Generally, digging down to the check valve or tank should be delayed until other more easily performed surface tests have failed to reveal the leak. If there is any doubt that the check valve seats tightly, repair it, replace it, or seal it off. Then repeat the pumping test and, if air is still entering the suction line, it may be assumed the pipe is leaking underground and it should be exposed for inspection. Dig carefully to avoid damage to the pipe which might make it impossible to verify whether a leak actually existed prior to uncovering.

4-3.6.4 If the pumps do not exhibit the symptoms of a leak as described above but there is still reason to suspect a pipe leak; or, if a complete system check has been performed and it is now necessary to isolate and check the piping system, individual pipe runs may be isolated and hydrostatic pressure tested.

4-3.6.5 A liquid volumetric pressure test can be performed on a suction line by connecting to the exit port of the air eliminator, or other appropriate fitting. This connection will permit pressure to be applied to the suction piping from the pump to the check valve. In this test, the hydrostatic pressure should not exceed 15 psi (103.4 kPa) in order to prevent damage to the pump.

4-3.7 Discharge Pipe Line Testing (Pipe under Pressure from Remote Pump).

4-3.7.1 Quite often pumps are located in the tank, or, on some rare occasions, just above the tank but remote from the dispensing devices. In such cases, the pipe to the dispensing equipment operates under pressure. A leak in this line will cause rapid loss of pressure after the pump is turned off. This can be checked using the procedure described in 4-3.5 or, if not practical, in the following manner.

4-3.7.2 At the dispenser end of the pipe, close the emergency shutoff valve at the base of the dispensers or close any valve upstream of any hose to hold pressure at the dispenser end. The pump end can be sealed off by setting the check and relief valves in the head of the pump. The check valve is readily accessible in the manhole over the pump, and most are equipped with a screw or bolt supplied for the specific purpose of positively seating these valves for line checking. Install a pressure gage in the line [a minimum 3 in. (76 mm) dial with maximum 60 psi (3100 mm Hg) range should be used to clearly show graduations of 1 psi (51.72 mm Hg)]. Generally, the best location for the gage is in the emergency shutoff valve under the dispenser where ¼-in. or other small-size plugs are installed for this purpose. Start the pump, note the maximum pressure, seat the check valve, turn off the pump and observe any pressure drop. The test should be maintained for at least 10 minutes. If the pressure drops, it indicates the possibility of a leak in the piping and it is recommended that a volumetric test be performed. It should be noted that a loss of liquid pressure can be attributed to the following: a line leak; a decrease in liquid temperature in the line; piping distortion due to the liquid pressure; or entrapped vapor in the piping. Accumulated liquid losses during a volumetric test of more than 0.05 gallons (0.19 liters) per hour during timed restoration may indicate a leak in the piping.

4-3.8 If the preceding tests do not reveal a leak, they should not be considered as conclusive and undergound piping must be included in the Precision Test described in 4-3.11.

4-3.9 Checking Underground Tanks.

4-3.9.1 Review the information obtained from the primary search described in Chapter 3. Ask about, observe, and note in particular:

(a) Method of filling tanks — damaged fill pipes, poorly maintained tight-fill connections or hose couplings, driver carelessness, or even overemphasis on full deliveries may cause some of the product to be spilled around the pipe when a delivery is made. Particularly, check fill pipes installed under manhole covers. On night deliveries in which the tank is filled into the fill pipe a warmer underground product temperature can cause considerable overflow due to expansion before dispensing begins the following day:

(b) Any evidence of ground settlement around tanks and any sign of work that may have damaged the tank or its fittings:

(c) History of past or recent work on the tanks or attached piping:

(d) The presence of excessive amounts of water in the tank and any history of past water removal. (Use water-finding paste on the gage stick.) Ascertain, if possible, if the water increases during periods of heavy rainfall and remains constant or diminishes during dry spells. Also, if possible, ascertain the depth of the water table, i.e., the static level of the groundwater, by using an easily drilled, probed, or excavated area close to the tank(s) or some existing undrained opening:

(e) The age of the tank; in particular, as it relates to the history of corrosion in the vicinity:

(f) The location and flow of liquid found underground by gas sensors or visual inspection. It may be advantageous to drive or drill additional holes to develop more detailed information.

4-3.9.2 Use this information to guide subsequent inspection and testing.

4-3.10 When Water is Reported to Be Entering a Tank.

4-3.10.1 Check the fill pipe to ensure that water is not entering through a loose fill cap.

4-3.10.2 Check the surface area around vent lines for evidence that water may be entering by this route. Standing water over vent lines may be the source. Note this possibility for future use.

4-3.10.3 If no explanation, except a possible leak, is found for water in the tank, carefully record the depth of water by water-finding paste, and tightly close and lock the fill cap. After 8 to 12 hours, remove the cap and again check for water. If the rise in 12 hours exceeds ½ in. (12.7 mm), close and lock the cap and check for another 8 to 12 hours. If the rise in the second period closely matches that of the first period, a leak is probable. A rise of less than ¼ in. (6.4 mm) in 8 hours is inconclusive due to the inability to measure the water level closer than to within ¼ in. (6.4 mm). Longer test periods will have to be used to determine definitely if a leak does, in fact, exist. Best results will be obtained if the water depth is less than 3 in. (75 mm) at the beginning of the test.

4-3.10.4 The above tests are not conclusive if the water table is above the top of the tank, as water could be entering around pipe connections into the tank top or through unused plugged or capped openings in the top of the tank that are not watertight. Also, if water is entering the tank at these top openings it is not significant from the standpoint of tank leakage. Likewise, these tests are not conclusive if the tank is full, or substantially full, of product.

4-3.10.5 In fact, water may not enter the tank if the level of product is at or above the level of the water table outside the tank. These tests are relatively effective if the tank is practically empty and the water table is high but still below the tank top. A tank partially below the water table can have water enter, or lose product, through the same leak depending on the relative levels of the groundwater and the product in the tank.

4-3.10.6 If a leak is indicated by the above test, take appropriate action.

4-3.11* Precision Test.

4-3.11.1 *Precision Test*, as used throughout this pamphlet, means any test that takes into consideration the temperature coefficient of expansion of the product being tested as related to any temperature change during the test, and is capable of detecting a loss of 0.05 gal (190 ml) per hour.

4-3.11.2 A test chosen from currently available technology to reasonably determine whether an underground liquid storage and handling system is leaking should be used. Any testing device used for the Precision Test must be capable of detecting leaks as small as 0.05 gal (190 ml) in one hour, adjusted for variables, a limiting criterion widely accepted by most authorities. Precision Tests should be performed by qualified technical personnel experienced in the use of the test method and in the interpretation of data produced.

4-3.11.3 The test procedure should measure the amount of liquid lost based upon fundamentally sound principles. It should detect a leak anywhere in the complete underground storage and handling equipment. If the net change exceeds 0.05 gal (190 ml) per hour or equivalent criterion established for the technology employed, a leak is likely to exist, and appropriate corrective action is necessary.

4-3.11.4 The Precision Test should account for all the variables that will affect the determination of the leak rate. An understanding of what these variables are and how they are handled is essential to effective performance of the test. Following is a discussion of some of those variables and how they affect the measurement.

4-3.12 The Effect of Temperature.

4-3.12.1 Liquids expand with an increase in temperature and contract with a decrease in temperature. Figure 2 lists the thermal coefficient of expansion for some of the more common flammable and combustible liquids.

4-3.12.2 For example, note that a temperature decrease of only 0.02°F (0.011°C) in one hour in a 6000 gal (22 710 L) tank containing gasoline would cause a volumetric decrease of 0.02°F (0.011°C) × 0.0007 × 6000 gal (22 710 L) = 0.084 gal (318 ml) which exceeds the 0.05 gal (190 ml) considered to indicate a leak. If this temperature change was not detected and accounted for in a test, a leak would be assumed where none existed. And in a like manner, if the temperature increased, a leak could be concealed by volumetric expansion if the temperature change was not detected.

4-3.12.3 It is sometimes proposed that this problem can be overcome by filling the tank 10 or 12 hours before a test run, on the assumption that the product temperature will stabilize. Extensive tests have shown that this is seldom if ever true. When liquid is added to fill a tank for testing, it will often require several days for the liquid to

Thermal Expansion of Liquids	Volumetric Coefficient of Expansion per Degree
Acetone	0.00085
Amyl acetate	0.00068
Benzol (benzene)	0.00071
Carbon disulfide	0.00070
Ethyl ether	0.00098
Ethyl acetate	0.00079
Ethyl alcohol	0.00062
*Fuel Oil #1 - Kerosene	0.0005
*Fuel Oil #2 - Diesel	0.00045
*Gasoline	0.0007
Methyl alcohol	0.00072
Toluol (toluene)	0.00063
Water — at 68°F	0.000115

*These are typical coefficients of expansion, but may vary depending on components of the mixture and on the temperature. See ASTM D 1250-80, Petroleum Measurement Tables, for further information.

Figure 2

stabilize to ground temperature, which in itself is constantly changing. The rate of temperature change in the first day or two will generally be in the range of 0.02°F (0.11°C) per hour to 0.25°F (0.7°C) per hour. In addition, the rate of temperature change will vary depending on the temperature and volume of the product in the tank as well as the product added. Obviously, the test must be capable of detecting temperature changes to the accuracy necessary to assure compliance with 4-3.11.

4-3.12.4 Another temperature effect that must be recognized and accounted for is temperature stratification or "layering." Layering occurs when product of a different temperature is added to product already in a tank (i.e., product is added to warmer product already in the tank); in addition, layering occurs as a result of ground temperature variations with depth. Temperature measurement must include a method for averaging any differences in temperature throughout the tank.

4-3.13 The Effect of Tank End Deflection.

4-3.13.1 Some techniques require filling the tank to a point above grade. This increase in height of liquid increases the pressure inside the underground tank over the normal operating pressure. This is illustrated in Figure 3.

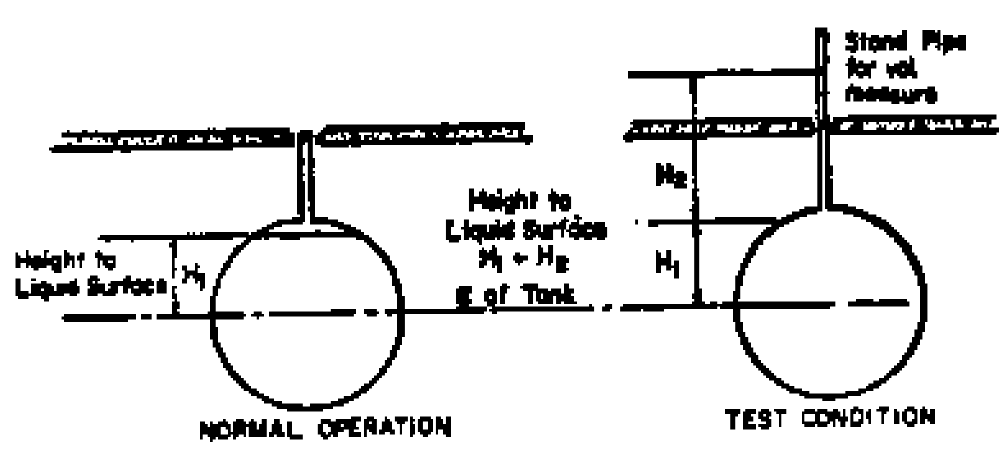

Figure 3

4-3.13.2 In a 6-ft (1.8-m) diameter tank the average pressure on the end or "head" of a tank full of typical gasoline is 0.98 psi (50 mm Hg). If the tank is buried 3 ft (1 m) under the driveway (typical for most gasoline tanks), the average pressure on the head will increase to approximately 2.95 psi (153 mm Hg) when the fill pipe and standpipe are filled to 3 ft (1 m) above grade. The increase of approximately 1.95 psi (100 mm Hg) in the average pressure exerts an additional force on the end or "head" of the tank of about 8000 pounds, or 4 tons.

4-3.13.3 Most tank ends[1] of the type normally used underground are made of ¼-in. (6.4-mm) thick steel plate and will deflect outward as pressure inside the tank increases. (*See Figure 4.*)

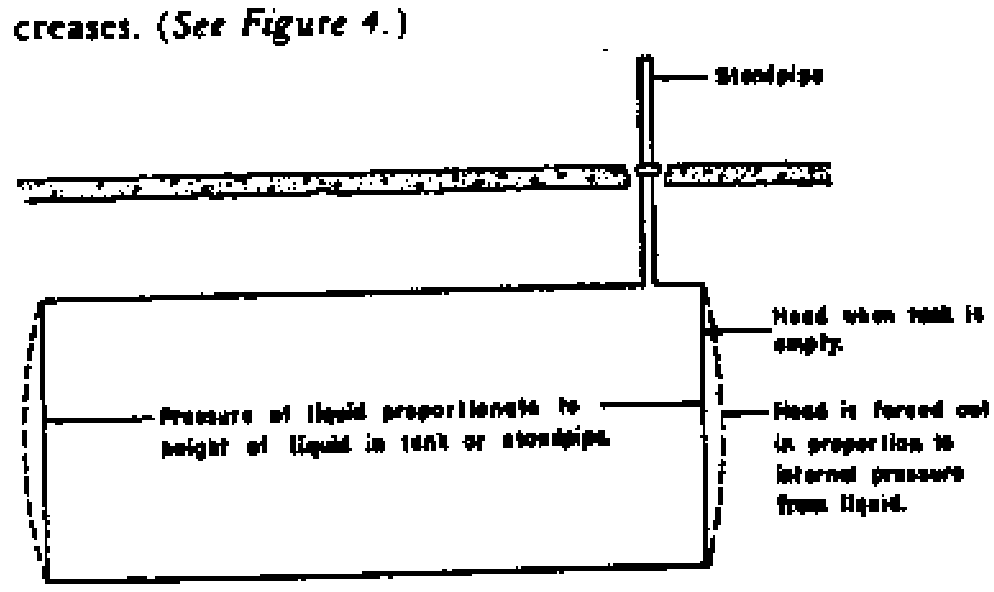

Figure 4 Tank End Deflection

4-3.13.4 If the tank is located above ground and the heads are not supported in any way, it is possible to predict the amount of movement that will result from any given change in pressure and, when the amount of movement is known, the resulting increase in volume of the tank can be calculated. However, when tanks are located underground they are subject to an infinite variation in support from the surrounding soil, and it is not possible to predict how much movement will take place. Very solid soil may provide close to full support, but normally soils will consolidate to some degree, particularly if they are wet, thereby allowing tank expansion and end deflection.

4-3.13.5 Extensive study and testing have revealed that in almost all cases tank movement significant to the test for leaks will occur. It will not occur suddenly because of the time required to consolidate the soil. Under a constant increased pressure it will normally take several hours for the tank to stabilize. The table in Figure 5 shows the volume increase as a result of various degrees of movement in the tank ends. The figures underlined are the maximum normally encountered with underground steel tanks; the last figure in each horizontal row is the maximum possible for the tank size in that row.[2]

The Precision Test method employed should be able to clearly indicate the possible effects of tank end deflection and either provide a means of compensation or elimination of the effects.

[1]Although most fiberglass tanks have oval or spherical ends, the same phenomenon of expansion will occur due to flexure between the ribs on the sides of the tank.

[2]Compatible figures are not yet available for fiberglass tanks. The latest data indicate that expansion due to side flexure may exceed that for flexure of steel tanks.

Apparent Loss of Liquid Volume in Gallons Due to Increased Pressure in a Tank

Outward Deflection at Center of Head in Inches

Tank Dia. Inches	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
48	.49	.98	1.47	1.95	2.44	2.93	3.42					
64	.87	1.74	2.61	3.48	4.35	5.22	6.10	6.97				
72	1.10	2.20	3.31	4.41	5.51	6.62	7.72	8.82	11.0			
84	1.50	3.00	4.50	6.00	7.50	9.00	10.50	12.00	15.0	18.0	21.0	
96	1.96	3.91	5.87	7.82	9.77	11.75	13.70	15.65	19.6	23.5	27.4	31.3
102	2.21	4.42	6.65	8.23	11.06	13.30	15.50	17.70	22.6	26.6	31.0	35.4
120	3.06	6.12	9.18	12.25	15.30	18.4	21.4	24.5	30.6	36.7	42.8	49.0

For SI Units: 1 in. = 25.4 mm.

Figure 5

4-3.14 The Effects of Water Table. As stated in subsection 4-3.10, there are many instances w re water may enter a tank system. The Precision Test method employed should be able to indicate cle y the possible effects of water in the backfill area around the tank system and provide a means of either compensation or elimination of the effects.

4-3.15 Effects of Entrapped Vapor. High-vapor-pressure materials combined with air in the form of a vapor-air pocket will be affected by both temperature and pressure changes; volume expansion or contraction will occur. Precision Test methods employed should be able to indicate the presence of entrapped vapor that may affect the results of the test. The test method must require the removal of the entrapped vapor or compensate for the effects of the entrapped vapor.

4-3.16 Effects of Evaporation. Some liquids, especially highly volatile liquids, have high rates of evaporative losses if their surfaces are exposed. The Precision Test method employed should be able to indicate clearly the possible effects of evaporative losses and compensate for them.

4-3.17 Water Testing.

4-3.17.1 Tests involving the addition of water to a tank may be useful when tanks are empty. Water is difficult to use in cold weather. It will not detect leaks of less viscous liquids, and contamination of the storage and dispensing system can be a major problem.

4-3.18 In summary, the following major factors must be accounted for in the Precision Test to determine the presence or absence of a leak in an underground liquid storage facility:

(a) The temperature change of the liquid in that period of time.

(b) The movement of tank ends as pressure is increased.

(c) Water table.

(d) Entrapped vapor.

(e) Evaporation.

Chapter 5 Tracing Liquids Underground

5-1 General. The *underground,* as referred to in this recommended practice, consists of an almost infinite variety of rocks and soils, tunneled, pierced, and trenched by man-made structures and pipes. All these provide paths for movement of liquid underground. Flow of liquid in tunnels, sewer pipes, and open trenches is obvious and relatively easy to trace by observation and vapor testing. Flow in soil and rocks is a complicated matter. A few basic principles will provide an understanding that will often prove sufficient to solve many problems of tracing the source of unconfined liquids. Even though such basic understanding may prove inadequate for a particular problem, it is essential to select and coordinate the particular expert skills necessary to solve the more complex problems.

5-2 Background.

5-2.1 The principal characteristic that permits liquids to enter, and accumulate or flow through soil or rock is porosity or, simply, the space or "voids" between the particles that make up the soil or rock. The size of the voids in soil will vary from large in gravel, through small in sand and topsoil, to essentially zero in fine, dense clay. Rock almost never has large voids but sandstones and limestones have voids similar to a fine sand.

5-2.2 Rate of flow through soils and rocks depends largely on the size of the voids; with large voids (gravel) the flow can be several feet per minute; medium voids (sand) will provide several feet per hour; and fine voids (shale or sandstone) may be as slow as one foot per day.

5-2.3 The term used to express this rate of flow is *pervious.* A very pervious soil will permit fast liquid flow; a relatively *impervious* soil will permit only very slow flow. When the word *impervious* is used alone, it implies no flow; thus glass is impervious to the flow of water.

5-2.4 Porosity does not ensure a pervious condition. If the pores of a rock are not interconnected, the rock will be impervious.

5-2.5 Crystalline rocks, such as granite and marble, are essentially impervious in their solid state but these rocks often have fractures or cracks that do permit flow. Rate of flow through rock fractures will vary from large continuous cracks which will act like a pipe, to very small irregular cracks which may result in flows similar to those found in fine sand.

5-2.6 Almost all flammable and combustible liquids are lighter than water and consequently they will float on water unless they are water soluble. When these liquids escape into the ground they will normally flow down to the water in the ground and there move with that water. An understanding of groundwater flow is essential to trace flammable and combustible liquids underground.

5-2.7 Water is almost universally found underground at some level in soil or rock. It may be in very limited quantities and only "dampen" the soil. But when it fills all the voids and "saturates" the soil or rock up to a certain level, it becomes similar to water in a pail and establishes a definite top, referred to as the water table.

5-2.8 Figure 6 illustrates that this groundwater may occur in several layers underground. A porous layer between two nonporous layers may be completely filled or it may be only partially filled and have its own water table.